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CARP, RIVER CARPSUCKER SMALLMOUTH BUFFALO AND BIGMOUTH BUFFALO IN LEWIS AND CLARK LAKE MISSOURI RIVER

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RESEARCH REPORT 69

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CARP, RIVER CARPSUCKER SMALLMOUTH BUFFALO AND BIGMOUTH BUFFALO IN LEWIS AND CLARK LAKE MISSOURI RIVER

Charles H. Walburg and William R. Nelson

Fishery Research Biologists

RESEARCH REPORT 69

UNITED STATES DEPARTMENT OF THE INTERIOR

Stewart L. Udall, *Secretary*

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FISH AND WILDLIFE SERVICE

Clarence F. Pautzke, *Commissioner*

BUREAU OF SPORT FISHERIES AND WILDLIFE

John S. Gottschalk, *Director*

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ABSTRACT

Studies of age composition, growth, length-weight relation, reproduction, year-class strength, and food habits were conducted from 1962 to 1964 on carp, river carpsucker, smallmouth buffalo, and bigmouth buffalo in Lewis and Clark Lake, a main stem Missouri River reservoir impounded in July 1955. Slow growth of these fishes was attributed to low standing crops of plankton and bottom fauna which may have resulted from excessive turbidity and rapid water exchange in the reservoir. All four species produced strong year classes in the 2 years following impoundment of Lewis and Clark Lake; reproduction since that time has been poor. These species did not produce year classes comparable in abundance to those which occurred following impoundment because of unfavorable environmental conditions. The probable major factor limiting successful reproduction was lack of rise in water level during the spawning period.

CARP, RIVER CARPSUCKER, SMALLMOUTH BUFFALO, AND BIGMOUTH BUFFALO IN LEWIS AND CLARK LAKE, MISSOURI RIVER

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North Central Reservoir Investigations, Bureau of Sport Fisheries and Wildlife, is studying main stem Missouri River reservoirs to relate effects of water management operations and other environmental factors on the fish populations. Studies were begun on Lewis and Clark Lake in 1962, and extended to include Oahe and Big Bend (Lake Sharpe) Reservoirs in 1964.

Studies of the fish population in Lewis and Clark Lake have indicated that carp, *Cyprinus carpio* Linnaeus, river carpsucker, *Carpiodes carpio* (Rafinesque), smallmouth buffalo, *Ictiobus bubalus* (Rafinesque), and bigmouth buffalo, *Ictiobus cyprinellus* (Valenciennes) experienced slow growth and irregular year-class survival since impoundment (Walburg, 1964). The purposes of the present study were to (1) describe life histories, (2) document changes in age-class composition, and (3) analyze the relation between environmentol variations and growth and reproduction. Carp and river carpsucker were the most abundant fishes in the reservoir; smallmouth buffalo and bigmouth buffalo were much less abundant (Walburg, 1964). These species were rarely taken by sport fishermen, and there was no commercial fishery.

The aid and suggestions of the staff of North Central Reservoir Investigations are gratefully acknowledged, especially Donald Swedberg for his assistance in fish aging. Analysis of fish stomach contents was completed by contract with South Dakota State College. Dr. Paul Eschmeyer reviewed the manuscript and made several valuable suggestions.

LEWIS AND CLARK LAKE

Lewis and Clark Lake is the smallest and southernmost of six main stem, multipurpose reservoirs constructed on the Missouri River by the U.S. Army Corps of Engineers. The reservoir is in southeastern South Dakota and forms part of a common boundary with Nebraska. It was created by the closure of Gavins Point Dam in July 1955 and has the following characteristics: maximum surface area, 28,000 acres; length, 21.2

miles; average width, 2.1 miles; maximum depth, 58 feet; average depth, 16 feet; shoreline length, 50 miles; and storage capacity, 450,000 acre-feet. Lake level is maintained between 1,204 and 1,208 feet, mean sea level, and weekly water level fluctuations rarely exceed 1 foot. This description differs slightly from that given in Walburg (1964) because we no longer consider the river-like area from Springfield, S. Dak., upstream to the mouth of the Niobrara River as part of the reservoir.

Before impoundment, downstream portions of the reservoir area were cleared of brush and trees, but numerous clusters of inundated trees remain in the upstream portion. The steep shoreline is essentially straight, except for a few narrow bays at the mouths of small tributaries. The bottom consists principally of silt, with isolated areas of sand, gravel, and rubble. Six small, intermittent streams enter the reservoir. The Niobrara River, with a mean daily flow of 1,750 c.f.s. (cubic feet per second), enters the Missouri River 9 miles above the reservoir. The Niobrara River carries a considerable load of sand and silt which is deposited in the upper end of the reservoir.

Lewis and Clark Lake is characterized by rapid exchange of water. During the navigation season (March-November), the entire storage capacity is passed through the dam every 8 to 10 days; in winter, complete water exchange is possible every 30 days. Water temperature rarely exceeds 28° C. (82° F.), and there is no thermocline. Dissolved oxygen concentration during the summer usually exceeds 80 percent saturation. Total alkalinity ranges from 140 to 177 p.p.m. (parts per million) and pH, from 7.8 to 8.2. Total hardness (as $CaCO_3$) ranges from 240 to 290 p.p.m. Conductivity ranges from 650 to 840 micromhos at 25° C. Summer turbidity ranges from 25 to 675 p.p.m. and is lowest near the dam (mean 30 p.p.m.) and highest in the headwaters (mean 180 p.p.m.) Secchi disk visibility normally ranges from 3 inches in the upper reservoir (mean 7 inches) to 38 inches (mean 24 inches) near the dam. Turbidity is influenced both by the Niobrara River and by wave action stirring the lake bottom and eroding banks. Winds of 30 to 50 miles per hour are not uncommon.

The Missouri River portion of the study area, located between Lewis and Clark Lake and Fort Randall Dam, is 50 miles long. Daily flow from March to November ranges from 17,000 to 40,000 c.f.s. and averages approximately 25,000 c.f.s.

MATERIALS AND METHODS

Fish were collected in 1962, 1963, and 1964, in conjunction with population-monitoring studies. Fishing gear included gill nets, with mesh sizes ranging from 1.5 to 7.0 inches stretch measure; frame nets, or modified fyke nets, with a mesh size of 2.5 inches stretch measure; 16- and 27-foot semiballoon trawls with ¼-inch liner in the cod; ¼-inch mesh bag seines; a 220-volt direct current electroshocker mounted on a boat; and Lake Erie trap nets (Ederer standard submarine trap net No. 10) with 1.5-inch stretch mesh in the crib and tunnel. Sampling was conducted between April and October each year. Frame nets, 16-foot trawls, bag seines, and the electroshocker were used in waters less than 10 feet deep and the remaining gear in deeper waters.

Scale samples, weight (grams), sex, and maturity were obtained from samples of fish collected. Total length (millimeters) was recorded for all fish.

Scale samples were selected to include the entire length range. A plastic impression of three or more scales from each fish was made for age and growth studies. Two biologists, working independently, read the scales using an Eberbach projector. Readings which disagreed were reexamined, and in most cases differences were reconciled. The opercular bone of carp was also used for age determination, as suggested by English (1952) and McConnell (1952). We concluded that scales were better indicators of age in this species because of incongruities in structure of opercular bones.

Previous workers have aged carp, river carpsucker, bigmouth buffalo, and smallmouth buffalo by the scale method. Validity of the scale method in this study was indicated by: (1) increase of average length with increase in number of annuli; (2) generally good agreement of back-calculated lengths at the end of different years of life as computed from the scales of fish of the same or different age groups and year classes; and (3) reappearance in successive years of dominant or weak year classes. The last criterion was demonstrated by the 1956 year class which dominated the catch of all four species since 1957 (Walburg, 1964). Age and growth studies on carp and river carpsucker were made on fish collected in 1962 and 1963. Growth calculations on these species were completed using the method of Fraser (1916). Age and growth studies on bigmouth buffalo and smallmouth buffalo were made on fish collected in 1964. Since few smallmouth buffalo less than age group V and bigmouth buffalo less than age group VII were collected, growth calculations on these species were made by direct proportion (Van Oosten, 1929).

Stomachs removed from fish collected between April and October in 1962 and 1963 were selected to include available sizes of each species. Stomachs were wrapped in gauze and preserved in 10 percent formalin. Contents of the anterior section of the digestive tract from the esophagus to the first major curve of the small intestine, and herein termed "stomach", were used for study of food habits. Individual stomach contents were emptied into a petri dish and macroorganisms were removed and identified. Remaining contents were placed in a 25 ml. (milliliter) graduate, diluted to 25 ml., mixed, and a 1-ml. sample was drawn and placed in a Sedgewick-Rafter counting cell for microscopic examination. Total counts of crustaceans were made; numbers of other organisms were estimated from counts of five longitudinal fields. Total number of food organisms was determined by multiplying sample counts by the dilution factor. Food habits of young-of-the-year were determined similarly, except stomach contents were diluted to 10 ml. Filamentous algae are included in the phytoplankton category.

Average volumes of food organisms found in stomach samples were calculated. Average dimensions of each organism were found by measuring up to 100 specimens. Formulae used to calculate volume were determined by shape (cube, cylinder, rectangular parallelepiped, sphere) of the organisms. Calculated volume of stomach contents in which little digestion had occurred closely approximated the centrifuged volume. Volume of unidentified digested material and fragments of organisms in each sample were found by subtracting the calculated volume for identified whole organisms from the centrifuged volume. Although it is recognized that some error in count or volume of food organisms could occur with this tech-

nique, proportionate numbers and volumes of food organisms should indicate the general food habits of each species.

CARP

Length and age compostion

Length of carp collected in 1963 ranged from 23 to 614 mm.; most fish were from 240 to 429 mm. long (table 1). Length-frequency distribution was stratified, and a random sample was aged from each 10 mm. group. Length range by age group was determined by aging 911 of 3,136 fish. Age ranged from young-of-the-year to age group XIII. Length range of age groups varied from 20 to 120 mm. There was considerable overlap in length between age groups, and length groups often contained three or four year classes.

Calculated growth

Body-scale relation was calculated from 1,639 carp collected in 1962 and 1963. No significant differences were found when the relation was computed separately by year and sex; therefore, the two years' data were combined. Relation between anterior scale radius and length was described by the straight line:

$$L = 18 + 1.59R$$

where L = total length in millimeters
and R = anterior scale radius (millimeters, X 27).

Time of growth initiation in 1963 was determined by combining age groups by time periods and examining scales for formation of the last annulus. Initiation of growth appeared to occur later in the year for older fish. Growth in length of mature fish was apparently delayed until spawning was complete. Annulus formation in fish through age group V was complete by mid-June. Annulus formation in older fish generally oc-

TABLE 1.—*Distribution, by length group and by age group, of carp from Lewis and Clark Lake, May-September 1963*

Total length	Number in age group—														Total
	0	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	
20–39 mm	8														8
40–59 mm	10														10
60–79 mm	7														7
80–99 mm	1														1
100–119 mm		1													1
120–139 mm		13													13
140–159 mm		58													58
160–179 mm		61	5												66
180–199 mm		43	4	3											50
200–219 mm		28	20	7	7										62
220–239 mm		4	16	2	17	4									43
240–259 mm				1	19	75	79	4							178
260–279 mm					2	38	272	124							436
280–299 mm							106	388	4						498
300–319 mm							2	351	90						443
320–339 mm								187	187						374
340–359 mm								22	219	20					261
360–379 mm									141	56					197
380–399 mm									27	110	3				140
400–419 mm										105	9				114
420–439 mm										30	41				71
440–459 mm										4	32				36
460–479 mm											17	8			25
480–499 mm											9	8			17
500–519 mm											1	5			6
520–539 mm												2			2
540–559 mm													3	7	10
560–579 mm														3	3
580–599 mm														3	3
600–619 mm														3	3
Total	26	208	45	13	45	117	459	1,076	668	325	112	23	3	16	3,136
Percent	0.8	6.6	1.4	0.4	1.4	3.7	14.6	34.3	21.3	10.4	3.6	0.7	0.1	0.5	99.8
Year class	1963	1962	1961	1960	1959	1958	1957	1956	1955	1954	1953	1952	1951	1950	

curred between late June and early July but was not complete until early August.

Since little difference was found between sexes in back-calculated length at end of each year of life, data were combined (table 2). Difference in length was evident between preimpoundment and postimpoundment year classes. In age group VII the difference was 60 mm. Average length attained by carp of the

TABLE 2.—*Calculated total length of carp at end of each year of life, Lewis and Clark Lake, 1962-63*

[Sexes combined; lengths in millimeters]

Year class	Number of fish	Mean length at end of year—														
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1962	91	143														
1961	38	125	186													
1960	16	99	157	191												
1959	30	104	160	202	235											
1958	69	94	156	196	220	245										
1957	230	90	156	197	221	240	264									
1956	424	88	167	207	235	256	275	294								
1955	282	82	179	225	258	282	304	320	340							
1954	208	81	194	240	279	309	337	359	376	392						
1953	113	90	198	257	298	333	368	389	405	420	443					
1952	39	82	177	242	289	327	365	379	421	439	453	482				
1951	16	97	174	244	293	332	376	425	446	466	480	491	533			
1950	21	112	179	250	314	356	402	444	471	492	509	524	538	568		
1949	7	109	177	262	304	349	380	437	470	494	521	538	552	564		
1948	8	100	165	241	303	347	384	433	477	505	536	554	570	582	595	
1947	1	135	184	219	258	324	426	452	517	560	580	593	608	621	633	642
Postimpoundment, 1956–62:																
Grand average calculated length		97	163	202	229	250	271	294								
Increment of average		97	66	39	27	21	21	23								
Preimpoundment, 1947–55:																
Grand average calculated length		85	186	237	276	306	334	355	375	416	462	505	544	572	599	642
Increment of average		85	101	51	39	30	28	21	20	41	46	43	39	28	27	43

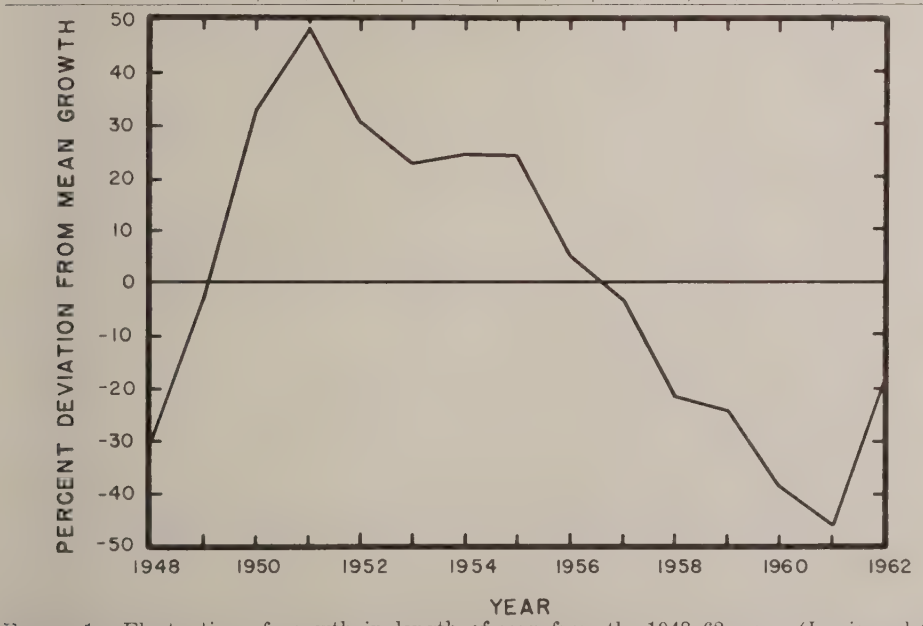

FIGURE 1.—Fluctuation of growth in length of carp from the 1948–62 mean (Lewis and Clark Lake impounded July 1955).

same age has generally declined each year since impoundment.

Percent deviation in mean growth was calculated following the method of Hile (1941). From 1950 to 1955, growth remained above average (fig. 1). With the change to a reservoir environment, growth steadily declined until 1962, when it improved for the first time.

Comparison of postimpoundment growth with that attained by this species in other waters illustrates slow growth in Lewis and Clark Lake (fig. 2). Fish from other Missouri River impoundments (Fort Randall Reservoir (Shields, 1958); Iahe Reservoir (Fogle, 1963) and Clear Lake, Iowa (English, 1952), showed considerably faster growth. Carp from Bear Lake, Utah (Sigler, 1958), also showed slow growth, but still exceeded that recorded in this reservoir.

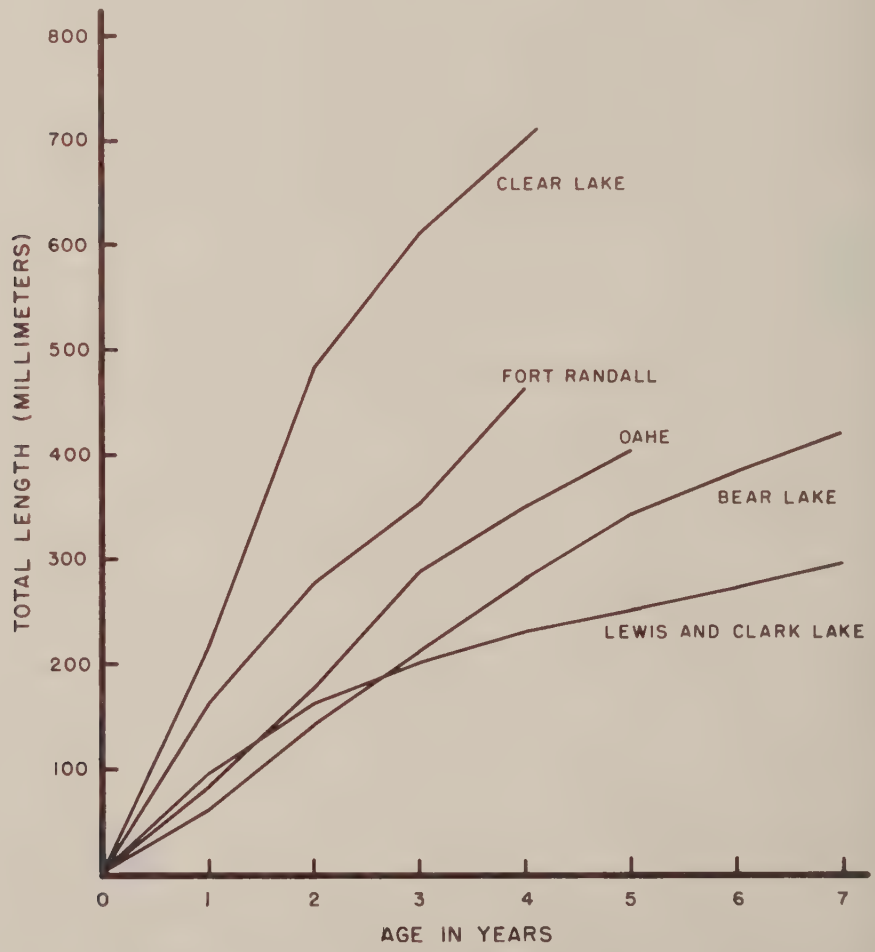

FIGURE 2.—Calculated length at end of each year of life of carp from Clear Lake, Fort Randall Reservoir (impounded 3 years), Oahe Reservoir (impounded 3 years), Bear Lake, and Lewis and Clark Lake (impounded 7 to 8 years).

Length-Weight Relation

Relation between length and weight of carp was determined from fish collected throughout the reservoir between April and September 1963. Data were grouped by 10-mm. length intervals, subsampled, and regression lines were computed by sex and location of capture. No biologically significant differences could be detected, and data were combined. Length-weight relation of the grouped sample (1,090 fish) was

$$\log W = -4.40758 + 2.79358 \log L$$

where W = weight in grams

and L = total length in millimeters.

Length-weight relation of all fish (1,333) treated as individuals was

$$\log W = -4.27661 + 2.73387 \log L.$$

The regression determined from grouped data approximated empirical weight more closely than the regression computed from individuals (table 3). With a larger sample, the regression calculated from individuals should better describe the relation between length and weight of Lewis and Clark Lake carp.

Carp from Lewis and Clark Lake weighed less at a given length than those from Oahe Reservoir, S. Dak. (Fogle, 1963), Clear Lake, Iowa (English, 1952), or Bear River Refuge, Utah (Sigler, 1958). At a length of 600 mm., weight of fish from these areas averaged 25 to 50 percent more than carp from Lewis and Clark Lake.

TABLE 3.—*Length-weight relation of carp, Lewis and Clark Lake, 1963*

[Length in millimeters; weight in grams]

Number of fish	Mean total length	Weight		
		Empirical	Calculated	
			Grouped [1]	Individual [2]
3	25	0.2	0.3	0.3
5	34	0.4	0.7	0.8
6	44	1	2	2
4	54	2	3	3
6	66	4	5	5
1	70	6	6	6
1	87	12	10	11
1	119	50	25	25
4	124	19	28	28
3	133	38	34	34
8	144	44	42	42
9	155	70	51	52
12	165	67	61	61
10	174	78	71	71
7	186	84	86	85
16	195	95	98	97
19	204	104	111	109
11	214	120	127	124
13	224	154	144	141
13	235	157	165	161
27	244	163	183	177
44	254	183	205	199
49	265	208	230	228
62	275	238	255	246
59	284	252	279	269
62	294	287	308	296
54	305	326	341	327
66	315	368	373	357
62	324	403	403	386
53	334	429	439	420
41	343	473	473	451
54	354	520	517	492
44	364	563	559	531
35	374	629	602	572
28	384	634	649	615
28	394	704	697	660
24	404	758	747	706
21	414	816	800	755
24	424	872	855	806
18	434	948	913	859
15	443	1,038	967	909
10	453	1,068	1,029	966
13	464	1,055	1,110	1,031
4	475	1,150	1,175	1,099
9	484	1,268	1,238	1,158
7	493	1,357	1,303	1,217
4	504	1,563	1,386	1,293
2	515	1,230	1,473	1,372
3	520	1,433	1,513	1,408
7	546	1,691	1,734	1,572
2	555	1,847	1,819	1,682
2	576	2,330	2,013	1,862
1	588	1,925	2,132	1,970
3	596	2,270	2,215	2,055
1	681	2,990	3,214	2,944

[1] Log W = −4.40758 +2.79358 log L.

[2] Log W = −4.27661 +2.73387 log L.

Reproduction and year-class strength

Examination of gonads of 657 carp collected in 1963 revealed that males first matured at age group IV and females at age group V. All males and 95 percent of females were mature at age group VIII. Some females old enough to be mature failed to develop eggs, possibly due to poor condition. Other females collected in August and September contained eggs that had not been deposited. English (1952) believed some females failed to spawn and resorbed their eggs. He also stated that all carp in Clear Lake, Iowa, were mature at age group II. These fish were the same length as age group IX fish from Lewis and Clark Lake.

Spawning habits of carp have been described by numerous authors. Greeley

(1928) reported that most spawning occurred at a water temperature range of 18.3° to 20.0° C. (65° to 68° F.). Sigler (1958) stated that spawning was initiated at water temperatures of 14.4° to 16.7° C. (58° to 62° F.). English (1952) reported that ripe females were collected in water of 21.7° C. (71° F.). Shields (1958) stated that most spawning occurred in water less than 1 foot deep when water temperature reached 16.7° to 20.0° C. (62° to 68° F.). Struthers (1931) found eggs randomly scattered on vegetation, debris, and exposed bottom at water depths of 6 inches to 3 feet. In Lewis and Clark Lake, males ripened during the latter part of May and females during June and early July. Spawning occurred between June 1 and July 15 with most activity in mid-June. Water temperature during this period ranged from 18.3° to 23.9° C. (65° to 75° F.).

Deviation in year-class strength of carp was determined by the method of el-Zarka (1959). In most preimpoundment years (1949-53), and since 1958, year-class strength has been weak (fig. 3). Strong year classes produced during the first years of impoundment (1955–57) still dominate the carp population.

Food habits

In this study, stomach contents of 267 carp were grouped by location and time of capture. Few differences were found

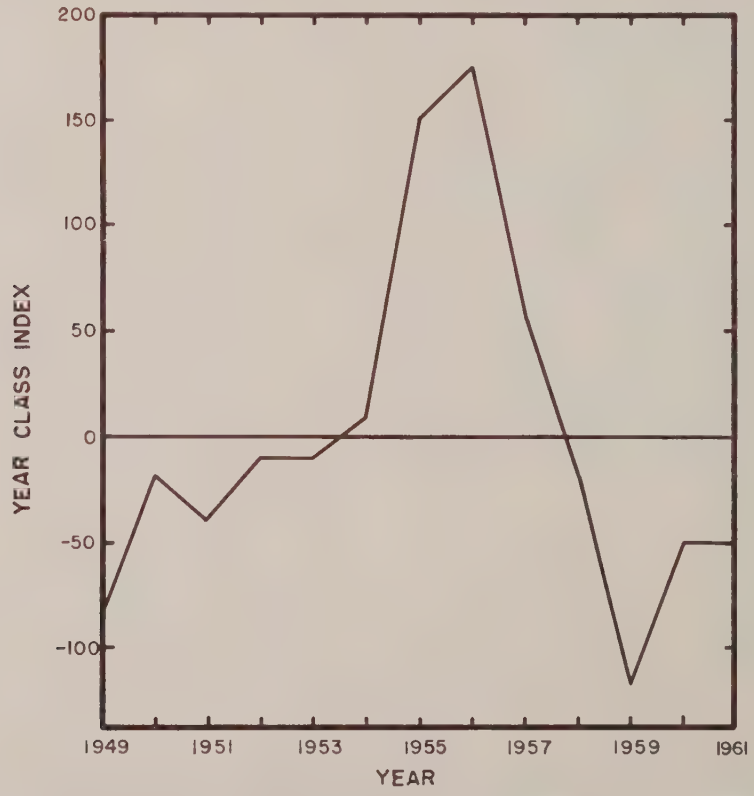

FIGURE 3.—Fluctuation in the relative strength of carp year classes, 1949–61 (Lewis and Clark Lake impounded July 1955).

in foods utilized, and data were combined (table 4). Food items in order of volumetric importance were organic detritus (61 percent), insects (19 percent), microcrustaceans (10 percent), and phytoplankton (9 percent). Organic detritus was composed of both plant and animal remains, but approximately 80 percent was of plant origin. Chironomid larvae and cyclopoid copepods were the major animal items in the diet. Chlorophyta (primarily *Mougeotia* and *Rhizoclonium*) constituted 6 percent of the diet and occurred in 24 percent of the stomachs. Diatoms occurred in 43 percent of the stomachs but owing to their small size, accounted for only 3 percent by volume. Young-of-the-year fed on phytoplankton, cyclopoid copepods, and chironomid larvae to a greater degree than adults.

Compared with investigations by Sigler (1958) in Utah, and Moen (1953) in Iowa, Lewis and Clark Lake carp ingested more plant food but less animal food (table 5). In two Iowa lakes, chironomid larvae, mollusks, and Malacostraca were important food items, but no algae were found to be ingested. Food habits of Lewis and Clark Lake carp were more similar to those recorded for Bear Lake, Utah, than for fish from two natural lakes in Iowa. Sigler (1958) stated that Bear Lake was poor carp habitat and that carp from this area were in poor condition.

Vass (1957) studied carp food habits in managed Indonesian ponds and concluded that microcrustaceans and chironomids were the predominate foods. In overstocked ponds, algae were an important food item when other foods became scarce. Growth rate decreased with increased utilization of algae.

TABLE 4.—*Stomach contents of carp collected from Lewis and Clark Lake, April-October 1962-63*

[Tr = Less than 1 percent]

Food item	Young-of-the-year		Adult		All fish	
	Percent occurrence	Percent volume	Percent occurrence	Percent volume	Percent occurrence	Percent volume
Phytoplankton	100	3	39	9	47	9
Cyanophyta			7	Tr	6	Tr
Chrysophyta	100	1	34	3	43	3
Chlorophyta	24	2	24	6	24	6
Seeds			1	1	1	1
Zooplankton	100	27	46	10	55	10
Rotifera			5	Tr	5	Tr
Crustacea	100	27	46	10	53	10
Cladocera			25	2	21	2
Copepoda	100	27	42	8	49	8
Insecta	94	19	39	19	46	19
Coleoptera			Tr	Tr	Tr	Tr
Diptera:						
Adult			1	Tr	1	Tr
Larvae	94	19	19	8	28	8
Odonata			1	Tr	1	Tr
Ephemeroptera			3	Tr	3	Tr
Hymenoptera			Tr	Tr	Tr	Tr
Unidentified:						
Adult			11	3	10	3
Larvae			10	7	8	6
Organic detritus	97	51	98	61	98	61
Sand and silt	3	Tr	4	Tr	3	Tr
Number of stomachs:						
With food	33		228		261	
Empty	2		4		6	

RIVER CARPSUCKER

Length and age composition

Length of river carpsucker collected in 1963 ranged from 16 to 496 mm.; most fish were from 270 to 359 mm. long

TABLE 5.—*Comparison of food habits of carp from Bear Lake, Spirit Lake, East Okoboji Lake, and Lewis and Clark Lake*

[Tr = Less than 1 percent]

Food item	Percent volume			
	Bear Lake [1]	Spirit Lake [2]	East Okoboji Lake [2]	Lewis and Clark Lake
Animal	55	92	75	29
Insects	22	59	48	19
Crustacea	32	23	9	10
Miscellaneous	1	10	18	Tr
Plant	32	8	25	71
Algae	1			9
Seeds	Tr	Tr	1	1
Detritus	31	8	24	61 [3]
Sand and silt	13			Tr
Number of stomachs	158	63	57	261

[1] Sigler (1958).

[2] Moen (1953).

[3] Approximately 80 percent was of plant origin.

(table 6). Age distribution was determined from a stratified random sample of 982 fish, grouped by 10 mm. lengths. Age ranged from young-of-the-year to age group XII. Lengths of fish 9 years old and older were included in age group IX+. Length range of age groups varied from 80 to 140 mm. with considerable overlap among age groups.

Calculated growth

Body-scale relation of river carpsucker was determined from a stratified random sample of 1,488 fish captured in 1962 and 1963. Fish were grouped in 10-mm. size classes by sex and year of capture. Body-scale relation was similar for both sexes and years and data were combined. Relation between average fish length and average anterior scale radius was linear and is expressed by the equation

$$L = 25.80 + 1.955\,R$$

where L = total length in millimeters
and R = anterior scale radius (millimeters, X27).

Scales collected in 1962 and 1963 indicated that annulus formation for most fish was completed between May 15 and June 15. All fish collected after the middle of July had complete annuli. Growth initiation of mature fish was apparently delayed until completion of spawning.

Comparison of back-calculated length at the end of each year of life indicated little difference between sexes and data were combined (table 7). Average growth increment decreased with age through the seventh year. Growth in length was greater for fish spawned before impoundment than for fish spawned after impoundment. Mean growth for years 1954 through 1962 was calculated using the method of Hile (1941). Average growth declined sharply after 1955 (fig. 4).

Growth of river carpsucker in Lewis and Clark Lake was slow compared with that attained by this species in other reservoirs (fig. 5). Fish from main stem Missouri River reservoirs—Oahe

TABLE 6.—*Distribution, by length group and by age group, of river carpsucker from Lewis and Clark Lake, May-September 1963*

Total length	Number in age group—										Total
	0	I	II	III	IV	V	VI	VII	VIII	IX+	
0–19 mm.	4										4
20–39 mm.	18										18
40–59 mm.	11	1									12
60–79 mm.	3	20									23
80–99 mm.		17									17
100–119 mm.		22	12								34
120–139 mm.		10	26								36
140–159 mm.		7	20								27
160–179 mm.			10	4							14
180–199 mm.			5	12	1						18
200–219 mm.			3	7	10						20
220–239 mm.				4	25	8					37
240–259 mm.					19	20	2				41
260–279 mm.					7	59	46				112
280–299 mm.					1	87	309	26			423
300–319 mm.						19	442	202			663
320–339 mm.							86	248	22		356
340–359 mm.							6	48	26		80
360–379 mm.								8	22		30
380–399 mm.									9		9
400–419 mm.									4	5	9
420–439 mm.									2	2	4
440–459 mm.										2	2
460–479 mm.										2	2
480–499 mm.										3	3
Total	36	77	76	27	63	193	891	532	85	14	1,994
Percent	1.8	3.8	3.8	1.4	3.2	9.7	44.6	26.7	4.3	0.7	100
Year class	1963	1962	1961	1960	1959	1958	1957	1956	1955	1954	

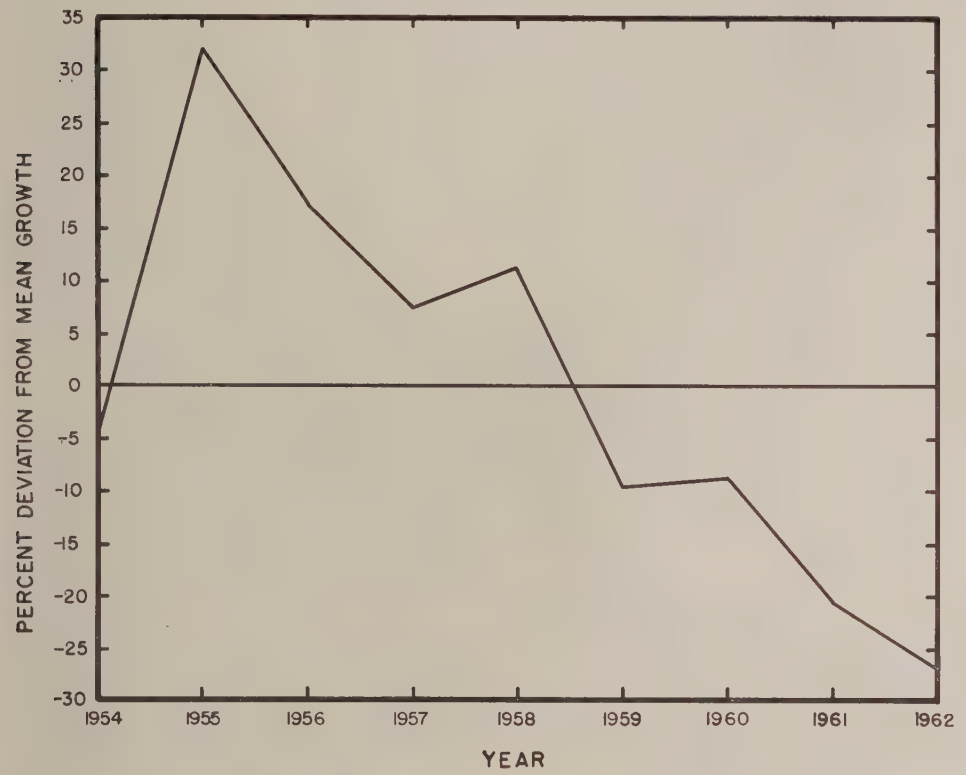

FIGURE 4.—Fluctuation of growth in length of river carpsucker from the 1954–62 mean (Lewis and Clark Lake impounded July 1955).

TABLE 7.—*Calculated total length of river carpsucker at end of each year of life, Lewis and Clark Lake, 1963*

[Sexes combined; length in millimeters]

Year class	Number of fish	Mean length (mm.) at end of year—									
		1	2	3	4	5	6	7	8	9	10
1962	63	59									
1961	49	68	114								
1960	23	61	117	168							
1959	41	68	124	173	214						
1958	96	69	134	191	232	267					
1957	450	67	134	185	227	259	286				
1956	214	67	127	184	224	260	287	312			
1955	37	70	129	181	228	265	302	331	354		
1954	7	66	134	181	236	291	332	373	400	422	
1953	2	57	104	159	237	288	350	382	407	435	452
Postimpoundment, 1956–62:											
Grand average calculated length		67	130	184	226	260	286	312			
Increment of average		67	63	54	42	34	26	26			
Preimpoundment, 1953–55:											
Grand average calculated length		69	129	180	230	270	309	340	363	425	452
Increment of average		69	60	51	50	40	39	31	23	62	27

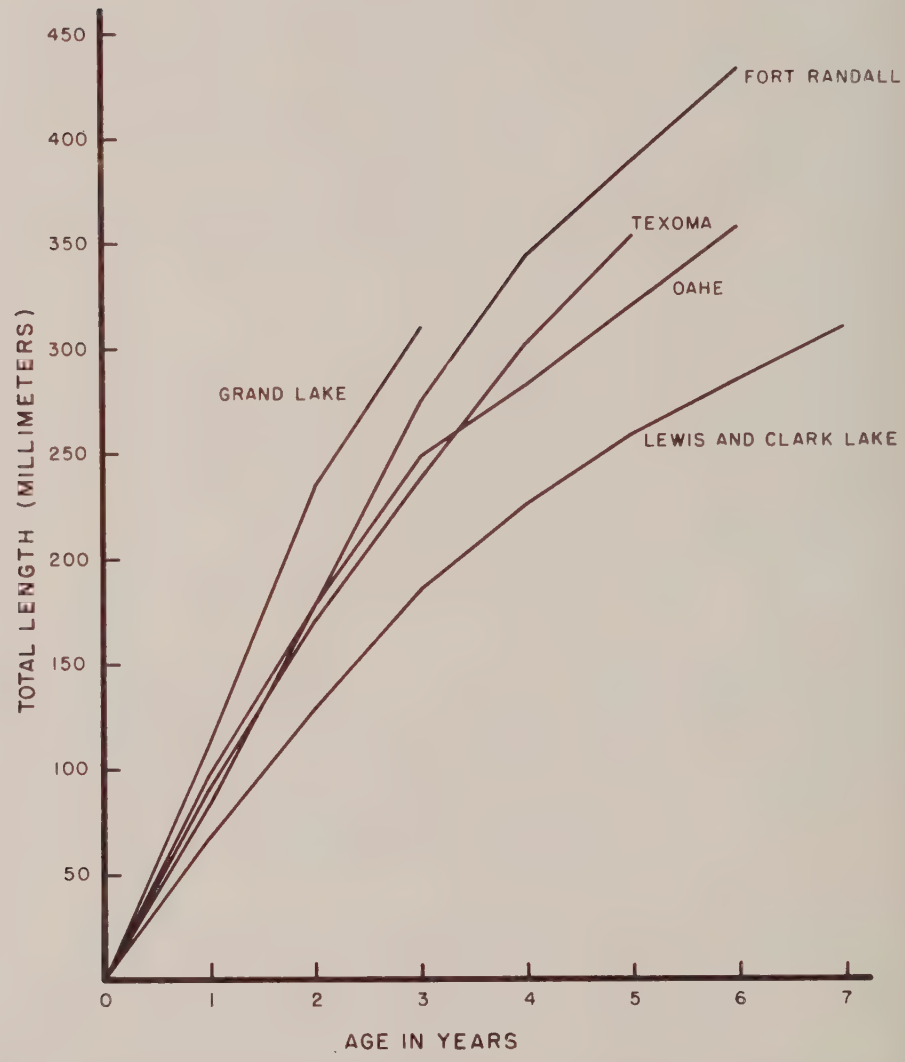

FIGURE 5.—Calculated length at end of each year of life of river carpsucker from Grand Lake (impounded 13 years), Fort Randall Reservoir and Lake Texoma (impounded 6 years), Oahe Reservoir (impounded 3 years), and Lewis and Clark Lake (impounded 8 years).

(Fogle, 1963) and Fort Randall (Sprague, 1961)—and from Grand Lake (Jenkins, 1953) and Lake Texoma (Bass and Riggs, 1959) in Oklahoma all had faster growth. River carpsucker from the Missouri River in Nebraska (Morris, 1965), Des Moines River in Iowa (Buchholz, 1957), and Salt River in Missouri (Purkett, 1958) were also reported to have faster growth.

Length-weight relation

Fish were grouped by 10-mm. size classes and the mean length and empirical weight determined for each interval (table 8). A subsample of 30 fish

was randomly selected for length classes exceeding this number of individuals. Length-weight relation of the grouped sample (487 fish) was expressed by the equation:

$$\text{Log } W = -4.72625 + 2.91662 \log L$$

where W = weight in grams

and L = total length in millimeters.

Length-weight relation of all fish (1,001) treated as individuals was:

$$\text{Log } W = -4.59291 + 2.85873 \log L.$$

Calculated weights were determined from these equations (table 8). Weights calculated from the regression of grouped data better approximated empirical weight. These regression equations must be considered of general application only, since the fish used for their calculation were collected from April through September and included both sexes.

Covariance analyses indicated a significant difference (5 percent level) in the length-weight relation of males and females both in slope of regression lines and in adjusted mean weights. Length-weight data were grouped by fish collected in April through June (includes spawning period) and July through September, and a significant difference (5 percent level) was found in the length-weight relation calculated for the two periods. Finally, the length-weight relation by sex was determined for fish collected July through September. Results indicated that there was no significant difference (5 percent level) between sexes in either slope of regression lines or adjusted mean weights for these fish. Differences in length-weight relation between sexes were probably caused by a greater increase in weight of females during the spawning period since no difference was found after spawning. Length-weight relation for all fish in the July through September sample was log $W = -4.47967 + 2.81250 \log L$.

At any given length the average weight of river carpsucker from Lewis and Clark Lake was less than that reported in Fort Randall Reservoir in South Dakota (Sprague, 1961) or Lake Texoma in Oklahoma (Bass and Riggs, 1959), but similar to fish from the Des Moines River in Iowa (Buchholz, 1957).

Reproduction and year-class strength

Some river carpsucker matured at age group IV, more than half were mature at age group V, and all were mature at age group VIII. Slight difference be-

TABLE 8.—*Length-weight relation of river carpsucker, Lewis and Clark Lake, 1963*
[Length in millimeters; weight in grams]

Number of fish	Mean total length	Weight		
		Empirical	Calculated	
			Grouped [1]	Individual [2]
6	43	1	1	1
3	57	2	2	3
12	66	4	4	4
10	75	5	6	6
8	86	8	8	9
9	97	11	12	12
6	106	13	15	16
11	117	25	20	21
13	126	39	25	26
11	137	34	32	33
9	146	43	38	39
10	154	50	45	46
3	165	69	55	56
7	174	59	64	65
11	186	76	78	78
6	198	88	94	94
6	204	88	100	100
9	216	113	121	120
12	225	137	136	135
11	236	139	157	155
6	246	162	177	175
13	255	190	196	194
21	265	212	220	216
30	276	236	247	243
30	286	268	274	269
30	296	288	303	296
30	305	324	331	323
30	315	357	363	354
30	324	396	394	384
30	334	433	431	419
18	345	481	474	459
13	354	516	511	494
4	368	544	572	552
6	375	573	604	583
2	390	700	678	652
4	395	710	703	676
2	410	705	784	752
3	417	830	824	790
4	426	914	876	839
2	432	922	913	873
1	448	1,000	1,015	969
2	454	1,210	1,055	1,007
1	468	1,140	1,153	1,098
1	474	1,170	1,197	1,139
1	498	1,515	1,382	1,311

[1] Log W = −4.72625 +2.91662 log L.
[2] Log W = −4.592916 +2.858731 log L.

tween sexes in age at maturity was noted. The smallest mature male was 223 mm. long, and smallest mature female was 218 mm. long. In the Des Moines River in Iowa, Buchholz (1957) found most mature females were from age groups IV through VII, but, the youngest mature female was from age group II and 244 mm. long. In the Missouri River in Nebraska, Morris (1965) found that 25 percent of age group III males and 25 percent of age group IV females were mature. Youngest mature fish were from age group II. The smallest mature male was 244 mm. long, and smallest mature female was 254 mm. long. Sexual maturity is apparently more related to fish growth than age.

River carpsuckers were not observed spawning, nor were ripe fish collected. Evidence of spawning was obtained from capture of near-ripe and spent fish. In 1963 spawning apparently occurred between June 13 and July 12, with most activity about June 24. Water temperatures during this period ranged from 21° to 24° C. (70° to 76° F.). According to Harlan and Speaker (1951), river carpsucker are shallow water, random spawners. Robert M. Jenkins[1] observed river carpsucker spawning in Great Salt Plains Reservoir in Oklahoma on June 7, 1948. Spawning occurred after dark between 8:30 and 10:30 p.m. over firm sand bottom on the leeward side of a large island in water 1 to 3 feet deep. Spawning was a noisy performance with much slapping at the water surface. Eggs were apparently broadcast loose in the water since a number were found adhering to the float line of a gill net nearby. Surface water temperature was 75° F. (23.9° C.).

Age-class distribution of river carpsucker collected by gill nets and frame nets from 1956 through 1962 (Walburg, 1964) and 1963 was used to determine relative strength of year classes. Fluctuation in relative year-class strength for the years 1952 to 1962 was calculated (fig. 6), after the method of el-Zarka (1959). The 1955 year class was strongest, followed by the 1956 and 1957 year classes. Reproduction or year-class survival after 1957 was poor.

Food habits

Analyses of river carpsucker stomach contents revealed that the most abundant food item was organic detritus, accounting for 69 percent of total stomach volumes (table 9). Plant detritus included partially digested phytoplankton and fragments of roots, stems, wood, and leaves. Animal detritus included partially digested zooplankton and insects. Zooplankton was the next most abundant food item, comprising 14 percent of stomach volumes, followed by phytoplankton with 3 percent and insects with 3 percent. The preponderance of detritus in stomachs probably accounts for a previous description of the food habits of this species as primarily unidentifiable material gleaned from the bottom ooze (Harlan and Speaker, 1951).

Diet of young-of-the-year was determined from 47 fish, 30 to 65 mm. long, caught in water less than 4 feet deep. Organic detritus composed 87 percent of stomach volumes; insects, 5 percent; and zooplankton, 2 percent (table 9). Detritus occurred in all stomachs; phytoplankton, 91 percent; zooplankton, 38 percent; insects, 6 percent; and nematodes, 2 percent. Chrysophyta, primarily diatoms, were the most abundant phytoplankton, and the dominant zooplankton were Copepoda. In the Des Moines River in Iowa, the most common foods

[1] National Reservoir Research Program, Fayetteville, Ark.

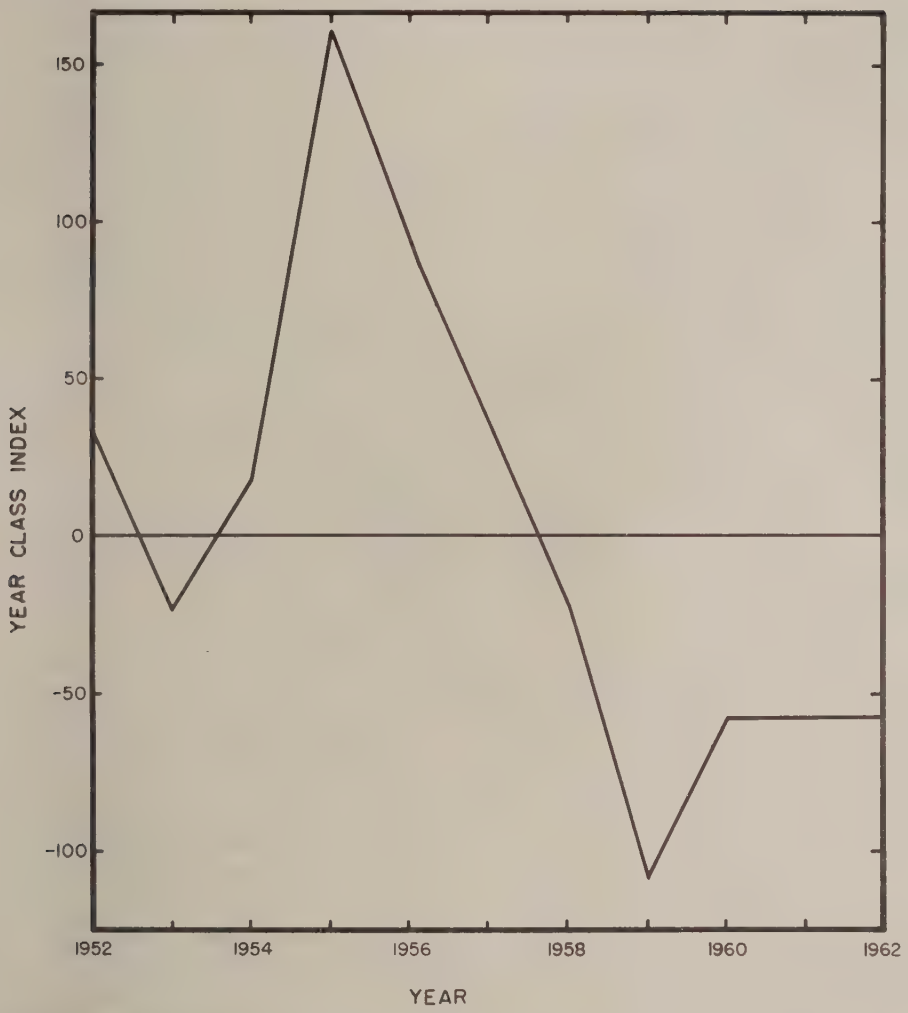

FIGURE 6.—Fluctuation in the relative strength of river carpsucker year classes, 1952–62 (Lewis and Clark Lake impounded July 1955).

of young-of-the-year river carpsucker were phytoplankton, followed by *Difflugia*, Diptera larvae, and Rotifera (Buchholz, 1957).

Food habits of age group I and older fish were determined from 121 fish, 65 to 368 mm. long. Most fish were from age group VI and VII. Organic detritus composed 67 percent of stomach volumes; zooplankton, 15 percent; phytoplankton, 3 percent; and insects, 3 percent (table 9). Food items, based on frequency of occurrence in stomachs, were diatoms (Chrysophyta), 57 percent; copepods, 41 percent; rotifers, 38 percent; green algae (Chlorophyta), 33 percent; and Cladocera, 27 percent. Important food items, based on percent of total volume, were copepods (primarily Cyclops), 52 percent; Cladocera (principally *Daphnia* and *Chydorus*), 19 percent; diatoms (primarily *Gyrosigma* and

TABLE 9.—*Stomach contents of river carpsucker collected from Lewis and Clark Lake, April-October 1962–63*

[Tr = Less than 1 percent]

Food item	Young-of-the-year		Adult		All fish	
	Percent occurrence	Percent volume	Percent occurrence	Percent volume	Percent occurrence	Percent volume
Phytoplankton	91	Tr	59	3	68	3
Cyanophyta	21	Tr	3	Tr	8	Tr
Chrysophyta	89	Tr	57	3	66	3
Chlorophyta	36	Tr	33	Tr	34	Tr
Zooplankton	38	2	61	15	55	14
Rotifera	19	Tr	38	Tr	33	Tr
Crustacea	32	2	51	15	46	14
Cladocera	4	2	27	4	21	4
Copepoda	28	Tr	41	11	38	10
Insecta	6	5	4	3	5	3
Diptera	6	5	4	3	5	3
Larvae	4	4	4	2	4	2
Adult	2	1	1	1	1	1
Nematoda	2	Tr	7	Tr	5	Tr
Organic detritus	100	87	100	67	100	69
Plant	91	65	81	55	84	56
Animal	11	22	28	12	23	13
Sand and silt	45	6	48	12	50	11
Number of stomachs:						
With food	47		121		168	
Empty	1		15		16	

Navicula), 14 percent; and diptera (chironomid larvae and adults), 14 percent. Quantity of various plankton genera in stomachs by season was similar to their general abundance in the reservoir (unpublished data, North Central Reservoir Investigations).

There was little variation in diet by age or season. These findings are in agreement with previous food habit studies by Buchholz (1957) and Brezner (1958). The occurrence of sand and silt in stomachs indicates this fish is a bottom feeder. Brezner (1958) concluded that the river carpsucker is probably a browser, feeding near the bottom and utilizing the periphyton associated with submerged rocks and debris. Except for fewer desmids, diptera larvae, and bluegreen algae, the diet of river carpsucker in Lewis and Clark Lake was similar to that reported for this species in other areas (table 10). However, it was noted that the diet of Lewis and Clark Lake river carpsucker contained less animal matter, which may account for their comparative slow growth. Detritus was not reported in previous food habit studies on river carpsucker. The importance of organic detritus in the diet of estuarine primary consumer fishes has been described by Darnell (1961).

TABLE 10.—*Percentage occurrence of food items in diet of river carpsucker from Des Moines River, Lake of the Ozarks, and Lewis and Clark Lake*

[Tr = Less than 1 percent]

Food item	Des Moines River [1]	Lake of the Ozarks [2]	Lewis and Clark Lake
Diatoms	71	48	66
Green algae	69	[3]	30
Bluegreen algae	55	[3]	8
Desmids	54	63	4
Diptera (immature)	41	26	4
Difflugia	37	Tr	
Rotifera	24	36	33
Copepoda	22	41	38
Cladocera	7	55	21

[1] Buchholz (1957).

[2] Brezner (1958).

[3] Filamentous algae occurred in 52 percent of stomachs.

SMALLMOUTH BUFFALO

Length and age composition

Lengths of smallmouth buffalo collected in 1964 ranged from 52 to 657 mm.; most fish were from 260 to 419 mm. long. No fish were captured in length ranges 130 to 259 mm. and 420 to 539 mm. (table 11). Age groups were O, I, and IV through XII, but 86 percent of fish were from age groups VI, VII, and VIII or year classes 1956, 1957, and 1958. Fish in the length range 260 to 419 mm. were spawned in the years following reservoir formation, and fish over 540 mm. long were spawned before impoundment. Extensive overlap occurred in length distribution among age groups.

Calculated growth

Study of scales revealed that annulus formation for most fish was completed

by the end of June. All fish collected after July 31 had complete annuli.

Since few preimpoundment fish were collected, presentation of growth calculations was limited to 1956 through 1960 year classes. Comparison of back-calculated length at end of each year of life indicated little difference between sexes, so data were combined (table 12). Growth increment in length was highest during the first year of life and declined in succeeding years. Growth of smallmouth buffalo was slower than in Oahe (Fogle, 1963) and Fort Randall (Sprague, 1961) Reservoirs in South Dakota, Grand Lake in Oklahoma (Thompson, 1950), or Watts Bar Reservoir in Tennessee (Martin, Auerbach, and Nelson, 1964) (fig. 7).

Length-weight relation

Length-weight relation of smallmouth buffalo was determined from 139 fish collected in April and May 1964 (table 13) and described by the formula:

Log $W = -4.94471 + 3.02043 \log L$

where W = weight in grams

and L = total length in millimeters.

TABLE 11.—*Distribution, by length group and by age group, of smallmouth buffalo from Lewis and Clark Lake, 1964*[1]

Total length	Number in age group—													Total
	0	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
40–59 mm.	2													2
60–79 mm.	7													7
80–99 mm.	1													1
100–119 mm.		3												3
120–139 mm.		1												1
140–259 mm.[2]														0
260–279 mm.					2	2								4
280–299 mm.						7	4							11
300–319 mm.						8	42	4						54
320–339 mm.							23	67	8					98
340–359 mm.							2	34	37					73
360–379 mm.								12	21					33
380–399 mm.									15					15
400–419 mm.									8					8
420–539 mm.[2]														0
540–559 mm.										4				4
560–579 mm.										2	2			4
580–599 mm.												2		2
600–639 mm.[2]														0
640–659 mm.													2	2
Total	10	4			2	17	71	117	89	6	2	2	2	322
Percent	3.1	1.2			0.6	5.3	22.0	36.3	27.6	1.9	0.6	0.6	0.6	99.8
Year class	1964	1963	1962	1961	1960	1959	1958	1957	1956	1955	1954	1953	1952	

[1] Age group O and I fish were collected in August; fish in other age groups were collected in April and May.
[2] No fish were captured in length ranges 140–259 mm.; 420–539 mm.; and 600–639 mm.

TABLE 12.—*Calculated total length of smallmouth buffalo at end of each year of life, Lewis and Clark Lake, 1964*

[Sexes combined; lengths in millimeters]

Year class	Number of fish	Mean length at end of year—							
		1	2	3	4	5	6	7	8
1960	2	74	186	230	267				
1959	10	84	159	233	265	288			
1958	38	82	156	234	271	295	316		
1957	48	84	160	231	268	292	317	336	
1956	32	88	167	242	275	302	327	346	367
Grand average calculated length		84	161	235	270	295	319	340	367
Increment of average		84	77	74	35	25	24	21	27

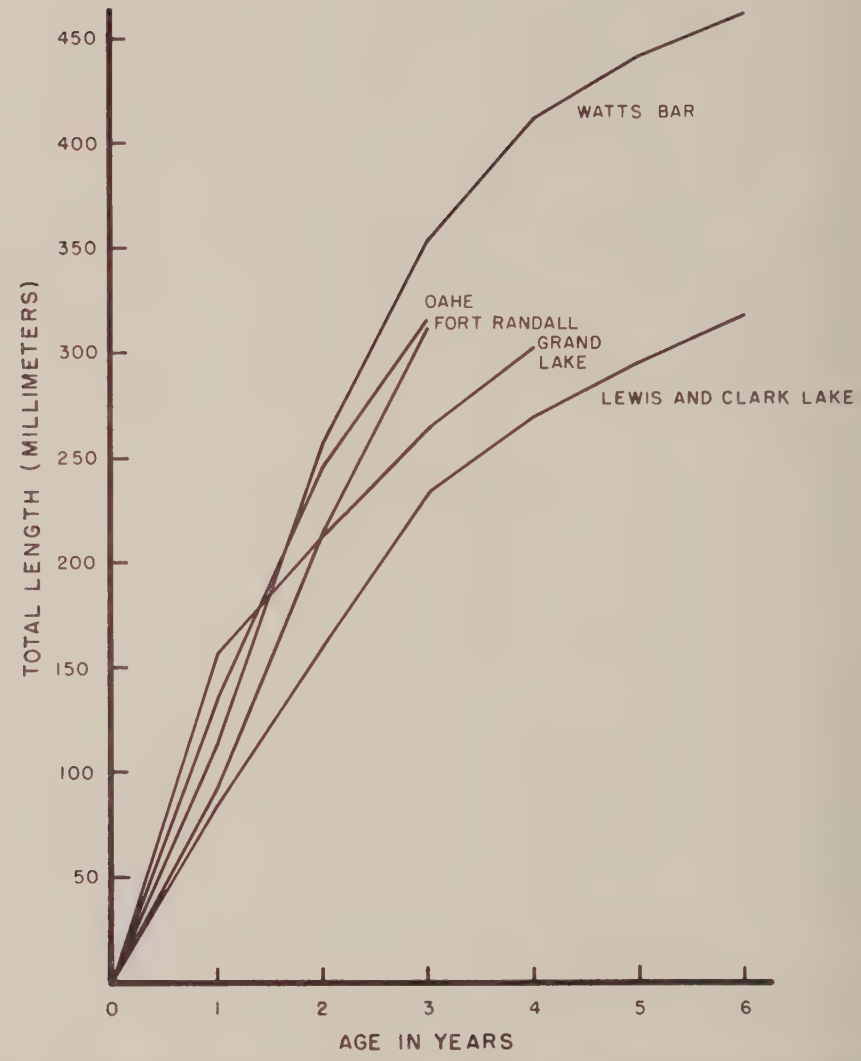

FIGURE 7.—Calculated length at end of each year of life of smallmouth buffalo from Watts Bar Reservoir (impounded 20 years), Oahe Reservoir (impounded 3 years), Fort Randall Reservoir (impounded 6 years), Grand Lake (impounded 8 years), and Lewis and Clark Lake (impounded 9 years).

At any given length the average weight of smallmouth buffalo was similar to that reported for this species in other waters (Jenkins, 1953; Fogle, 1963; Martin et al., 1964).

Reproduction and year-class strength

Males matured at an earlier average age and smaller size than females. Some males matured at age group VII, and all were mature by age group IX. Some females matured at age group X, and all were mature by age group XI. Studies in Fort Randall Reservoir in 1956 (Shields, 1958) indicated that 50 percent of both male and female small-

mouth buffalo were mature at age group III. These fish averaged 350 mm. in length and 630 g. in weight, which is comparable to the size of age groups VII and VIII fish in Lewis and Clark Lake. In Arkansas ponds, both male and female smallmouth buffalo attained maturity at age group II and weighed approximately 450 g.[2] Earliest mature males from Lewis and Clark Lake also weighed approximately 450 g. Apparently, size rather than age determines maturity of this species. Alm (1959) studied the relation among maturity, length, weight, and age in fishes and concluded that, in general, fast-growing fishes of the same species matured at an earlier average age than slow-growing fishes.

TABLE 13.—*Length-weight relation of smallmouth buffalo, Lewis and Clark Lake, 1964*
[Length in millimeters; weight in grams]

Number of fish	Mean total length [1]	Weight	
		Empirical	Calculated
3	265	240	237
1	274	280	262
3	286	280	298
2	296	320	331
7	302	356	352
25	314	379	395
25	324	421	435
14	334	470	476
18	344	519	521
11	353	563	563
5	365	638	623
7	374	667	671
3	384	760	726
2	391	810	767
3	405	843	853
1	412	970	898
2	548	2,080	2,126
2	567	2,220	2,357
1	575	2,425	2,459
2	595	3,152	2,726
1	634	3,140	3,318
1	652	3,490	3,644

[1] No fish were captured in length range 420–539 mm.

Smallmouth buffalo spawning was not observed, but a ripe female was collected on May 25, 1964, and most mature fish collected after June 20 had spawned. Water temperatures during this period ranged from 16.7° to 21.1° C. (62° to 70° F.). Harlan and Speaker (1951) reported that smallmouth buffalo spawned in May in Iowa, and that eggs were deposited at random over the bottom or on vegetation. Martin et al. (1964) reported spawning in sloughs and shallow, weedy areas.

Smallmouth buffalo catches in Lewis and Clark Lake were dominated by the 1956, 1957, and 1958 year classes (table 11). From previous fish collections (Walburg, 1964), it appears that the 1956 year class was strongest, followed by the 1957 and 1958 year classes. Year classes established after 1959 were weak.

Food habits

Diet of smallmouth buffalo from Lewis and Clark Lake was determined by McComish (1964), and much of the following description was taken from his thesis. Only six young-of-the-year, 35 to 64 mm. long, were captured. Copepods and cladocerans made up 99 percent of stomach contents, and sand constituted the remainder.

Food habits of adults were determined from 271 fish, 250 to 400 mm. long, and from age groups III through VII. Zooplankton were found in 78 percent of stomach samples; insects, 52 percent; phytoplankton, 38 percent; and sand, 50 percent. Unidentifiable digested material and plant debris were found in 72 percent and 23 percent of stomachs, respectively (table 14). Zooplankton contributed 28 percent to stomach volumes. Copepods (*Cyclops, Diaptomus, Eucyclops*) composed 78 percent of zooplankton volumes and cladocerans (*Bosmina, Chydorus, Daphnia*), the remainder. Phytoplankton and filamentous algae constituted 16 percent of stomach volumes. Chlorophyta (*Cladophora, Mougeotia, Oedogonium, Ulothrix*) accounted for 38 percent of volumes and

[2] Personal communication, Dr. J. H. Stevenson, Fish Farming Experimental Station, Stuttgart, Ark.

Chrysophyta (*Cymbella, Fragilaria, Gyrosigma, Navicula*), 62 percent. Insects (primarily chironomids) contributed 4 percent to stomach volumes. Unidentifiable, digested material constituted 49 percent of stomach volumes; woody and herbaceous plant fragments, 1 percent; and sand, 2 percent.

Diet of adult smallmouth buffalo, as determined from volume of identifiable material, was as follows: zooplankton, 55 percent; phytoplankton, 31 percent; insects, 8 percent; sand, 4 percent; and plant debris, 2 percent. There was little change in diet of fish grouped by size, depth of collection, or location of capture within the reservoir. There was variation in diet with time, which is probably related to availability of organisms. The presence of sand and plant debris in stomachs suggests that these fish usually feed at or near the bottom.

TABLE 14.—*Stomach contents of adult smallmouth buffalo collected from Lewis and Clark Lake, April-October 1962-63* [1]

[Tr = Less than 1 percent]

Food item	Percent occurrence	Percent volume
Phytoplankton	38	16
Chlorophyta	28	6
Chrysophyta	26	10
Zooplankton	78	28
Crustacea	76	28
Cladocera	47	6
Copepoda	72	22
Rotifera	16	Tr
Hydracarina	3	Tr
Insecta	52	4
Diptera	47	4
Other	7	Tr
Digested material [1]	72	49
Plant detritus [2]	23	1
Sand	50	2
Number of stomachs:		
With food	255	
Empty	16	

[1] Unidentifiable digested material and mucous.

[2] Woody and herbaceous plant fragments.

BIGMOUTH BUFFALO

Length and age composition

Length of bigmouth buffalo collected in 1964 ranged from 23 to 635 mm.; most fish were from 430 to 529 mm. long. No fish were captured in the length range 80 to 369 mm. (table 15). Catches were composed of five age groups, but most fish were from age groups VII and VIII or year classes 1956 and 1957. None was collected from age groups I through V. Less than 2 percent of fish captured were from year classes spawned before formation of the reservoir.

Calculated growth

From examination of bigmouth buffalo scales collected in 1962 and 1963, it was determined that annulus formation was complete by the end of June. Some fish formed annuli during the last week of May and all fish collected in July had newly formed annuli.

Catches of adult bigmouth buffalo were composed of fish from the 1955, 1956, 1957, and 1958 year classes. Fish of the 1955 year class attained greater length at a given age than those from

TABLE 15.—*Distribution, by length group and by age group, of bigmouth buffalo from Lewis and Clark Lake, 1964* [1]

Total length	Number in age group—						Total
	0	I-V [2]	VI	VII	VIII	IX	
20–39 mm.	7						7
40–59 mm.	4						4
60–79 mm.	8						8
80–359 mm. [3]							
360–379 mm.			2				2
380–399 mm.				5			5
400–419 mm.			1	4			5
420–439 mm.				17	6		23
440–459 mm.				37	20		57
460–479 mm.				17	48		65
480–499 mm.					71		71
500–519 mm.					38		38
520–539 mm.					19		19
540–559 mm.					4		4
560–579 mm.					2	2	4
580–599 mm.						1	1
600–619 mm.						1	1
620–639 mm.						1	1
Total	19		3	80	208	5	315
Percent	6		1	25.4	66	1.6	100
Year class	1964		1958	1957	1956	1955	

[1] Age group O fish were collected in July and August; fish in other age groups were collected in April and May.

[2] No fish between age groups I and V were captured.

[3] No fish were captured in length range 80 to 359 mm.

TABLE 16.—*Calculated total length of bigmouth buffalo at end of each year of life, Lewis and Clark Lake, 1964*

[Sexes combined; lengths in millimeters]

Year class	Number of fish	Mean length at end of year—							
		1	2	3	4	5	6	7	8
1958	2	118	203	272	319	354	390	----	----
1957	44	115	208	277	332	378	413	442	----
1956	138	116	210	285	343	391	432	466	492
Grand average calculated length		116	209	283	340	387	427	460	492
Increment of average		116	93	74	57	47	40	33	32

later year classes. Since few preimpoundment fish were collected, presentation of growth calculations was limited to postimpoundment year classes. Comparison of back-calculated length at end of each year of life indicated little difference between sexes and data were combined (table 16). There was a progressive decrease in growth increment with increase in age.

Growth of the bigmouth buffalo in Lewis and Clark Lake was slow compared with growth by the species in Oahe Reservoir (Fogle, 1963) and Fort Randall Reservoir (Sprague, 1961) in South Dakota and in Grand Lake (Jenkins, 1953) in Oklahoma (fig. 8). Growth of this species in Saskatchewan was slower than that found in Lewis and Clark Lake and cause for slow growth was attributed to the cold climate and population density (Johnson, 1963).

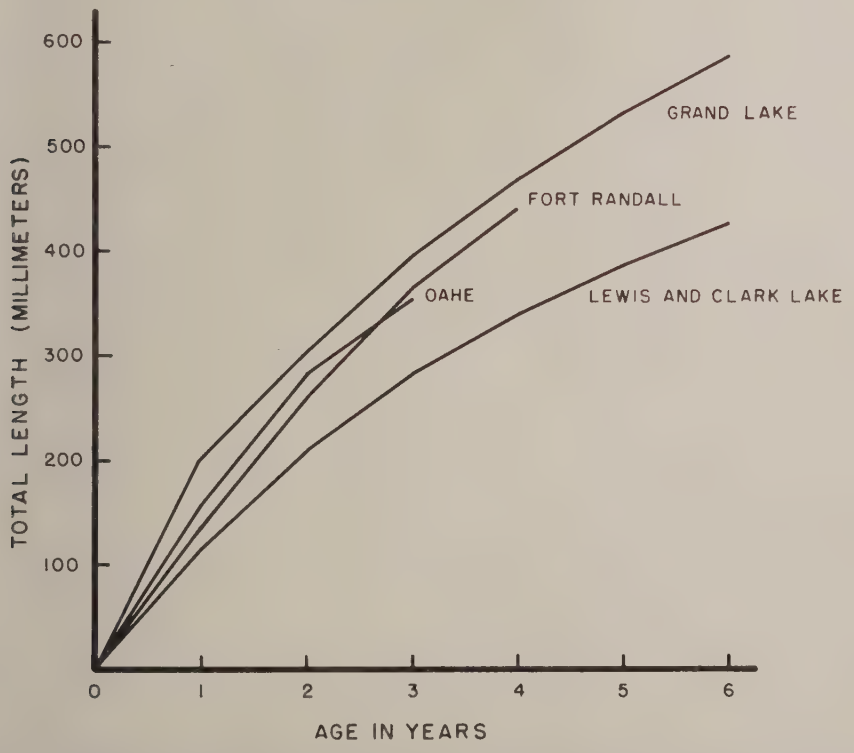

FIGURE 8.—Calculated length at end of each year of life of bigmouth buffalo from Grand Lake (impounded 13 years), Fort Randall Reservoir (impounded 6 years), Oahe Reservoir (impounded 3 years), and Lewis and Clark Lake (impounded 9 years).

Length-weight relation

The length-weight relation of bigmouth buffalo was determined from 187 fish collected in April and May 1964 (table 17) and described by the formula

$$\text{Log } W = -5.55997 + 3.27604 \log L$$

where W = weight in grams
and L = total length in millimeters.

At any given length, average weight of bigmouth buffalo from Lewis and Clark Lake was similar to that found for this species in Grand Lake in Oklahoma (Jenkins, 1953) and Reelfoot Lake in Tennessee (Schoffman, 1943).

TABLE 17.—*Length-weight relation of bigmouth buffalo, Lewis and Clark Lake, 1964*

[Length in millimeters; weight in grams]

Number of fish	Mean total length	Weight	
		Empirical	Calculated
1	375	700	746
1	389	840	841
2	391	830	855
2	406	925	967
2	415	1,070	1,040
4	424	1,115	1,115
15	436	1,267	1,222
11	445	1,406	1,306
11	454	1,403	1,395
21	465	1,504	1,509
18	474	1,647	1,606
18	486	1,769	1,744
26	494	1,874	1,840
16	504	2,006	1,964
14	515	2,105	2,108
12	524	2,294	2,231
5	532	2,226	2,345
3	540	2,493	2,462
1	559	2,770	2,758
2	564	2,820	2,839
1	580	3,020	3,112
1	631	3,960	4,101

Reproduction and year-class strength

Males matured at an earlier average age and smaller size than females. Most age group VII and all age group VIII males were mature. Some females (25 percent) were mature at age group VIII and most (67 percent) were mature at age group IX. The oldest immature female, captured on May 4, 1964, was from age group IX and was 568 mm. long. Shields (1958) studied age at maturity of bigmouth buffalo in Fort Randall Reservoir in South Dakota in 1956 and found that 90 percent of males and 95 percent of females were mature at age group III. These fish averaged 375 mm. in length and 815 g. in weight, which is comparable to the size of age group VI and VII fish in Lewis and Clark Lake.

Johnson (1963) found that bigmouth buffalo in Saskatchewan were all mature at a fork length of 480 mm. (approximately 525 mm. total length). Few females younger than age group X were mature. Johnson reported that "the condition of the gonads of 360 females less than 19.0 inches (480 mm.) long (probably from age group VII to IX) was determined, and of these only 19 were mature." He further stated that most males matured at a fork length of 379 mm. (approximately 413 mm. total length). Thus the fish from Saskatchewan matured when 1 to 2 years older than those in Lewis and Clark Lake.

This species apparently spawns at an earlier average age in southern latitudes. Swingle (1957) implied that bigmouth buffalo matured at age group I or older in Alabama ponds. Brady and Hulsey (1959) reported that age group I males in Arkansas ponds were usually mature and females immature; both sexes were mature at age group II. Compared with other areas, maturation of bigmouth buffalo in Lewis and Clark Lake and Canadian waters was extremely slow.

Evidence of bigmouth buffalo spawning was first obtained on May 20, 1964, with the capture of a ripe female. All mature females captured after June 15 had spawned. Mature males were ripe both before and after these dates. Water temperatures during this period ranged from 16.7° to 20.0° C. (62° to 68° F.). Spawning was not observed, although it has been reported to be an obvious

performance which involves splashing in shallow water (Mosher, 1885, and Canfield, 1922). Swingle (1954) reported that spawning in ponds was heaviest when water temperatures ranged between 15.6° and 18.0° C. (60° to 65° F.). Canfield (1922) stated that most eggs adhere to floating vegetation.

Catches of bigmouth buffalo were composed of five year classes. Percent of catch by year class in 1964 was as follows: 1955, 1.6 percent; 1956, 66.0 percent; 1957, 25.4 percent; 1958, 1.0 percent; and 1964, 6.0 percent (table 15). Since reservoir formation, strong year classes were produced only in 1956 and 1957. Few young-of-the-year were collected during the summers of 1962, 1963, or 1964, and no age group I fish were collected.

Food habits

Stomach analyses were conducted on 261 young-of-the-year, 16 to 47 mm. long (McComish, 1964). Ninety-eight percent were collected in shallow bays at water depths less than 3 feet. Zooplankton composed 100 percent of stomach volumes (table 18). Copepods (principally *Cyclops, Diaptomus,* and *Eucyclops*) composed 80 percent of stomach volumes and cladocerans (principally *Chydorus* and *Daphnia*) 11 percent. Rotifers (*Brachionus* and *Keratella*) made up 9 percent of total stomach volumes. Insects (chironomid larvae) and phytoplankton (*Pediastrum*) contributed little to the diet. Johnson (1963) found copepods and cladocerans to be the most important food organisms of young buffalo in Pasqua Lake in Saskatchewan.

Adult diet was determined from 125 fish 330 to 530 mm. long and from age groups IV through VII (McComish, 1964). No fish in age groups I through III were collected. Sixty-five percent of the fish were collected from water less than 4 feet deep, and the rest were taken in depths of 8 to 10 feet. Zooplankton composed 100 percent of stomach volumes (table 18). Copepods

TABLE 18.—*Stomach contents of bigmouth buffalo collected from Lewis and Clark Lake, April-October 1962-63*

[Tr = Less than 1 percent]

Food item	Young-of-the-year		Adult	
	Percent occurrence	Percent volume	Percent occurrence	Percent volume
Phytoplankton	1	Tr	3	Tr
Chlorophyta	1	Tr	3	Tr
Chrysophyta			1	Tr
Zooplankton	100	100	100	100
Crustacea	74	91	100	100
Cladocera	37	11	48	15
Copepoda	61	80	64	38
Fragments			69	47
Rotifera	74	9	7	Tr
Insecta	2	Tr	1	Tr
Sand			5	Tr
Number of stomachs:				
With food	259		120	
Empty	2		5	

(*Cyclops, Diaptomus, Eucyclops*) and cladocerans (*Bosmina* and *Daphnia*) composed 53 percent of stomach volumes, and fragments of these organisms made up 47 percent. Studies of the food habits of bigmouth buffalo from northwest Iowa lakes showed that this fish fed principally on small crustaceans (Moen, 1954). Similar results were found in studies on Pasqua and Echo Lakes in Saskatchewan (Johnson, 1963). Phytoplankton and insects contributed little to the adult diet. These results are in agreement with Moen (1954), Scidmore and Woods (1959), and Johnson (1963). Johnson noted, however, that there was a distinct trend toward increased insect (chironomids) consumption with increase in size of fish. Study of food habits in Lewis and Clark Lake revealed little change in diet of fish grouped by size, depth of

collection, or location of capture within the reservoir.

DISCUSSION

Growth of carp, river carpsucker, smallmouth buffalo, and bigmouth buffalo was slower in Lewis and Clark Lake than in comparable large reservoirs and lakes of the United States. Particularly significant was the finding that growth was slower than that of the same species in Fort Randall and Oahe Reservoirs, both of which are located on the Missouri River in South Dakota. These species, considered primary feeders, are in direct competition for available plankton and bottom fauna. Carp, river carpsucker, and smallmouth buffalo fed on phytoplankton, zooplankton, and aquatic insects; bigmouth buffalo fed on zooplankton (table 19).

Of the fishes studies, carp growth was slowest. Carp fed to a greater degree on plant material than reported in other areas. Vass (1957) found that in overstocked ponds carp fed on algae, and with increased utilization of algae, growth rate decreased.

Poddubnyy and Fortunatov (1961) reviewed fish feeding conditions in Russian plains reservoirs and mentioned a decrease in benthos after the first few years of impoundment. Fishes dependent on benthos exhibited a decrease in growth, transition to a planktonic diet unfamiliar to older fish, and increased detritus content in intestines. It was suggested that the nutritive value of detritus was low. It was also suggested that the poor development (standing crop) of benthos in most Russian reservoirs was caused by an unfavorable diet for invertebrates and not because the latter were heavily cropped by fish.

Both Fort Randall and Oahe Reservoirs are relatively deep and clear, while

TABLE 19.—*Comparison of food habits of adult* [1] *carp, river carpsucker, smallmouth buffalo, and bigmouth buffalo, Lewis and Clark Lake*

[Tr = Less than 1 percent]

Food item	Percent volume			
	Carp	River carpsucker	Smallmouth buffalo	Bigmouth buffalo
Phytoplankton	9	3	16	Tr
Zooplankton	10	15	28	100
Insecta	19	3	4	Tr
Nematoda		Tr		
Detritus [2]	62 [3]	67	50	Tr
Sand and silt	Tr	12	2	Tr
Number of stomachs with food	228	121	225	120

[1] Fish other than young-of-the-year.

[2] Unidentifiable digested material of plant and animal origin.

[3] Includes 1 percent seeds.

Lewis and Clark Lake is shallow and turbid. The bottom of the latter is composed of extensive areas of silt, and because it is shallow high winds cause sudden and marked changes in turbidity. During the summer of 1964, turbidity measurements ranged from 25 to 675 p.p.m., depending on tributary runoff, wind, and location in reservoir. Since turbidity was mostly wind induced, duration of extreme turbidities was temporary. The high turbidity in the reservoir may reduce phytoplankton abundance, since photosynthesis is limited by the depth of the euphotic zone (Verduin, 1956).

Average standing crop of zooplankton in the reservoir, from July through September 1964, was less than two organisms per liter.[3] Between July and October 1962, average standing crop of bottom fauna in the reservoir was 11 kg./ha. (wet weight; 91 percent *Hexagenia*)[3]. This appears much lower than comparable standing crop data from other waters (Sublette, 1957; Townes, 1938). Buck (1956) and others have found that high turbidity limits production of fish foods and has a de-

trimental effect on growth and reproduction of scaled fishes. Darkness (turbidity) also limits the feeding ability of fishes (Ivlev, 1961).

Apparently, slow growth of these species in Lewis and Clark Lake was caused by low standing crops of plankton and bottom fauna. Since the latter foods were not available in sufficient quantity, these fishes—particularly carp and river carpsucker—utilized plant material and detritus which are of apparent low nutritive value of these species. Present knowledge indicates that low standing crops of plankton and bottom fauna were caused by excessive turbidity and by rapid water exchange rate through the reservoir (complete water exchange possible every 8 to 10 days), which does not allow formation of a "stable" lacustrine community.

Recent studies [3] of *Hexagenia* in Lewis and Clark Lake show that density increased from 11 kg./ha. (wet weight) in 1962 to 29 kg./ha. in 1964. Increase in *Hexagenia* abundance is not expected to affect significantly growth of the species discussed since this organism was not an important item of diet in Lewis and Clark Lake or other areas (Brezner, 1958; Buchholz, 1957; Johnson 1963; Moen, 1953, 1954; Sigler, 1958) where comparable food habit studies have been conducted.

Strong year classes of carp, river carpsucker, smallmouth buffalo, and bigmouth buffalo were produced in the 2 years following closure of Gavins Point Dam in July 1955. Year classes produced since 1958 have been weak. Successful reproduction of these species is apparently dependent on rising water levels during the spawning period. Canfield (1922), Walker and Frank (1952), and Swingle (1954, 1957) stated that spring flooding activated buffalo spawning. They also suggested that spawning may be delayed until desirable conditions occurred. Tarzwell (1941) pointed out the possibility of controlling carp reproduction in large reservoirs by fluctuating the water level at spawning time. Shields (1958) concluded that planned water level drawdown on Fort Randall Reservoir was primarily responsible for poor carp reproduction. Gavins Point Dam was closed July 31, 1955, and the water rose 18 feet in 5 days, where it remained into the winter months. In June 1956 the water rose 14 feet in 20 days. Between June and August 1957 the reservoir water level increased 3.5 feet. Since 1957, May-August water elevations have usually been maintained between 1,204 and 1,208 feet above mean sea level. May-June water levels have been generally low because of the flood control function of the reservoir.

Comparison of water levels with year-class strength suggests that rising water levels during the June-August period are necessary for successful spawning and survival of these species. Successful spawning during the first years of impoundment may have been related to flooding of lowlands and grass areas. At present the water rises and falls over essentially bare shoreline consisting of silt, sand, and rubble. Most shoreline is subject to heavy wave action. Buck (1956) and other have pointed out the adverse effect of silt and turbidities in excess of 100 p.p.m. on the spawning success of some fish species. Spawning may also be effected by daily water level fluctuations of 6 inches or more caused by upstream power-peaking operations at Fort Randall Dam.

Studies in Oahe Reservoir (Parsons, 1963–64) further illustrate the beneficial effect of flooding during the spawning

[3] Unpublished data, North Central Reservoir Investigations.

period on reproduction of these species. Age distribution of fishes taken in the fall of 1963 by trap net indicated that 92 percent of the carp, 14 percent of the river carpsucker, 87 percent of the smallmouth buffalo, and 96 percent of the bigmouth buffalo were of the 1962 year class. Since closure of Oahe Reservoir on July 31, 1958, water levels during the spawning period have changed little except in 1962, when they rose 18 feet. The relation between flooding during spawning period and year-class survival was less pronounced for river carpsucker. The following statement concerning bigmouth buffalo by Johnson (1963) may well apply to all species in this study: "buffaloes are more typically inhabitants of rivers than of lakes, and that while existence in lakes is possible, flourishing population must be associated with a river or nearby marsh with regular spring floods."

It is concluded that limited food supply was responsible for slow growth of carp, river carpsucker, smallmouth buffalo, and bigmouth buffalo in Lewis and Clark Lake. These species were unable to produce year classes comparable in abundance to those which occurred during the 2 years following reservoir formation because of unfavorable environmental conditions. The primary factor limiting successful reproduction was probably lack of rise in water level during the spawning period.

SUMMARY

The Bureau of Sport Fisheries and Wildlife, in the U.S. Department of the Interior, is conducting studies on main stem Missouri River reservoirs to relate the effect of water management operations and other environmental factors on the fish populations. Lewis and Clark Lake, created by the closure of Gavins Point Dam in July 1955, is the lowermost reservoir in the chain.

Initial investigations on Lewis and Clark Lake indicated that carp, river carpsucker, smallmouth buffalo, and bigmouth buffalo have experienced slow growth and irregular year-class survival since impoundment. The purposes of this study were to describe life histories, document changes in age composition, and analyze the relation between environmental variations and growth and reproduction.

Fish samples were obtained between April and October in 1962, 1963, and 1964 by various types of fishing gear. Data from these collections were used to determine age composition, growth, length-weight relation, reproduction, year-class strength, and food habits.

Growth rates of carp, river carpsucker, smallmouth buffalo and bigmouth buffalo in Lewis and Clark Lake were slower in both length and weight than in other reservoirs, large lakes, or rivers. Particularly significant was the finding that growth was slower than that of the same species in Fort Randall and Oahe Reservoirs on the Missouri River in South Dakota. Fort Randall and Oahe Reservoirs are relatively deep and clear, while Lewis and Clark Lake is shallow and turbid.

Apparently, slow growth of these species in Lewis and Clark Lake was caused by low standing crops of plankton and bottom fauna. Since the latter foods were not available in sufficient quantity, these fishes, particularly carp and river carpsucker, utilized plant material and detritus which are of apparent low nutritive value. Present knowledge indicates that low standing crops of plankton and bottom fauna were caused by excessive turbidity and by rapid water exchange through the reservoir.

Strong year classes of carp, river carpsucker, smallmouth buffalo, and bigmouth buffalo were produced in the 2 years following closure of Gavins Point Dam in July 1955. Year classes produced since 1958 have been weak. Successful reproduction of these species is apparently dependent on rising water levels during the spawning period. It was concluded that these species were unable to produce year classes comparable in abundance to those which occurred in the 2 years following reservoir formation because of reservoir water level management practices.

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